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NATURAL REPRODUCTION OF GRAND FIR AND MOUNTAIN HEMLOCK AFTER SHELTERWOOD CUTTING IN CENTRAL OREGON

by

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ABSTRACT

The establishment and survival of grand fir and mountain hemlock seedlings in the Oregon Cascades were determined for a 2-year period following shelterwood cutting and a good seed crop. Mortality of both species was heavy; 71 percent of the fir and 90 percent of the hemlock seedlings initially established died. Number of seedlings per milacre was significantly correlated with amount of residual overstory; more seedlings of both species were established, and survival of grand fir was better, as stand density increased. Drought was not a mortality factor during the second summer, since seedling moisture stresses never became critical.

Keywords: Regeneration (natural), shelterwood cutting method, timber management planning.

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There has been a recent increase in demand for logs from the true fir-mountain hemlock forests of the Oregon Cascades. Despite the increased utilization of this timber resource, little is known about silvicultural systems best suited for obtaining natural regeneration. Until recently, primarily clearcutting was used to harvest true fir-mountain hemlock stands on National Forest lands. In some cases, natural regeneration of true fir has been adequate (Gratkowski 1958), but in many others little or no natural regeneration has occurred (Franklin 1965*a*, Franklin and Smith 1974).

Recognizing that shade-tolerant species found in the fir-hemlock type might regenerate better after partial cutting, the Deschutes National Forest began using the shelterwood method in 1971. This paper reports the natural regeneration of grand fir (*Abies grandis* (Dougl.) Lindl.) and mountain hemlock (*Tsuga mertensiana* (Bong.) Carr.) following a good seed year in response to variations in density of the residual stand. 2/

STUDY AREA AND METHODS

The study area is located in the Three Sisters Province, Oregon High Cascades (Franklin 1965*b*), about 30 miles (48.3 km) southwest of Bend, Oregon, in the Deschutes National Forest at an elevation of about 5,500 feet (1,678 m). The soil is a well-drained, sandy loam regosol, developing on ash and pumice of recent volcanic origin. Considerable amounts of rock and gravel are present. The volcanic layer is underlain at a depth of about 2 feet (0.6 m) by a buried soil which contains very few roots, thus limiting root depth to the upper ash and pumice profile.

Average annual precipitation is about 25 to 35 inches (63 to 89 cm) with much of this occurring as snow. Summers are short with little rainfall, and freezing temperatures can occur any month of the year.

Before cutting, the 146-acre (59-ha) study area supported a well stocked (200 to 250 ft^2 of basal area per acre; 46 to 57 m^2 per hectare) stand of mountain hemlock, grand fir, western white pine (*Pinus monticola* Dougl. ex D. Don), and lodgepole pine (*Pinus contorta* Dougl.) that averaged about 25,000 gross bd. ft. (Scribner) per acre. There were about 100 trees per acre, of which 85 percent were mountain hemlock, 8 percent grand fir, 5 percent white pine, and 2 percent lodgepole pine. Average diameter was about 18 inches (46 cm) for hemlock and 26 inches (66 cm) for grand fir.

After cutting was completed, there were about 15 to 20 trees per acre (37 to 49 trees per hectare) remaining. About 80 percent of these were hemlock, 18 percent fir, and a few white pine and lodgepole pine made up the balance. Density of the residual stand was not uniform over the entire area, ranging from small openings to groups of trees. Slash was piled with a bulldozer and burned, resulting in abundant exposure of mineral soil over most of the area.

After cutting was completed in the fall of 1971, 43 systematically spaced, 1-milacre plots (.00041 ha) were established in the study area. On each milacre, the total number of seedlings of each species, resulting from the 1971 seedfall, was recorded in the spring and fall of 1972 and 1973. At each milacre, basal

2/ The results reported here are based on an inventory of natural regeneration after a commercial timber sale rather than from a formal study.

area of the residual stand was measured with a 10-factor prism.

During the summer of 1973, soil moisture content was measured gravimetrically at depths of 6, 12, 18, and 24 inches (15, 30, 45, and 60 cm), and soil moisture tension (soil matric potential) was estimated from the soil moisture depletion curve for each depth. Moisture stress (xylem pressure potential) of grand fir seedlings (1 to 2 inches tall; 2.5 to 5 cm) was measured periodically during the second growing season with a portable pressure bomb as described by Waring and Cleary (1967). All measurements were taken during the hours from 0900 to 1400 P.s.t. on seedlings in full sunlight except for June 26, when stresses were measured from 0400 to 2000 hours to determine predawn values and recovery from peak stresses.

Surface temperatures of soil and litter in open areas and under groups of trees (partial shade) were determined with Tempils[3/] having melting points of 125°, 138°, 150°, and 163° F (51.7°, 58.9°, 65.6°, and 72.8° C).

The relationship of residual stand density to initial seedling establishment and survival was analyzed by fitting the data after logarithmic transformation by linear least squares to a parabolic, exponential, and power curve model and selecting the model that accounted for the most variation in seedling numbers.

RESULTS AND DISCUSSION

Seedling Establishment and Survival

As a result of the good cone crop produced by upper slope species in 1971,[4/] an average of almost 4,000 seedlings per acre (9,880 per hectare) (total of both species) were found the following spring (table 1). About 70 percent of these seedlings were grand fir, although only about 18 percent of the residual overstory was fir. As might be expected, the greatest mortality of both species occurred during the first summer, when 41.5 percent of the fir seedlings and almost 80 percent

[3/] Tempils are small, aspirin-sized tablets, with various melting points. Manufactured by Tempil Corporation, 132 W. 22nd St., New York, N.Y. Trade name of product is mentioned solely for necessary information. No endorsement by the U.S. Department of Agriculture is implied.

[4/] See Franklin et al. (1974) for cone yield ratings of upper slope species. In 1971, cone production ranged from medium to very heavy throughout the Oregon and Washington Cascades.

Table 1.--*Average number of seedlings per acre, with standard errors, and cumulative mortality after shelterwood cut, by species and date*

Species	Seedlings per acre				Cumulative seedling mortality at end of:					
	1972		1973		Summer 1972		Winter 1972-73		Summer 1973	
	Spring	Fall	Spring	Fall						
	Number				*Number*	*Percent*	*Number*	*Percent*	*Number*	*Percent*
Fir	2,744 ± 548	1,605 ± 429	930 ± 376	791 ± 329	1,139	41.5	1,814	66.1	1,953	71.2
Hemlock	1,186 ± 330	256 ± 111	163 ± 88	116 ± 76	930	78.4	1,023	86.3	1,070	90.2
Total	3,930 ± 818	1,861 ± 484	1,093 ± 407	907 ± 342	2,069	52.6	2,837	72.2	3,023	76.9

of the hemlock died. At the end of the second growing season, 71 percent of the fir and 90 percent of the hemlock seedlings were dead. At this time, the average number of fir seedlings had been reduced to 791 per acre (1,954 per hectare), and there were only 116 hemlock seedlings per acre (286 per hectare) remaining. No white pine or lodgepole pine seedlings were found on the milacres.

It was very obvious, from casual observation of the pattern of seedling establishment in the study area, that the seedlings were not distributed uniformly over the area. Most of them were found under or near groups of overstory trees, but very few occurred in openings of any size. These observations were confirmed by analysis of the relationship between number of seedlings per milacre and overstory density. The number of grand fir seedlings initially established in the spring of 1972 and the number surviving in the fall of 1973 were exponentially related to stand density; that is, the number of seedlings per milacre increased with increasing stand density. Correlation between these variables was significant at the 1-percent level (spring 1972) and 5-percent level (fall 1973)(fig. 1). Despite other unaccounted for sources of variation such as aspect and seedbed condition on the milacres, stand density alone accounted for 73 percent of the variation in the number of grand fir seedlings established in 1972 and 57 percent of the variation in the number of seedlings surviving after two growing seasons (fig. 1).

Although there were fewer mountain hemlock than grand fir seedlings established per milacre, the same exponential relationship between seedling numbers and stand density was found for hemlock (fig. 2). More hemlock seedlings were found as the overstory became denser, and a highly significant amount of the variation (71 percent) in numbers of seedlings established in 1972 was accounted for by stand density.

The initial establishment of both fir and hemlock seedlings was favored by a denser overstory, but there was a striking contrast in the mortality of these species as related to stand density. As density of the residual stand increased from 50 to 100 ft^2 per acre (11.5 to 23 m^2 per hectare), mortality of fir seedlings at the end of 2 years decreased from 100 to 46 percent (table 2). On the other hand,

Table 2.--*Average number of seedlings per milacre and mortality by species, date, and residual stand density*

Basal area at milacre (square feet)	Seedlings per milacre				Mortality after two growing seasons	
	Spring 1972		Fall 1973			
	Fir	Hemlock	Fir	Hemlock	Fir	Hemlock
	Number				*Percent*	
0	1.0	0	0	0	100	--
10	1.2	.4	.2	.2	83	50
20	.5	.2	0	0	100	100
30	2.9	.9	.4	0	78	100
40	2.5	1.3	.5	.5	80	62
50	1.5	.3	0	.2	100	50
60	2.8	1.8	.8	0	71	100
70	4.0	1.5	1.0	0	75	100
90	13.0	3.5	6.0	0	54	100
100	6.5	6.0	3.5	0	46	100

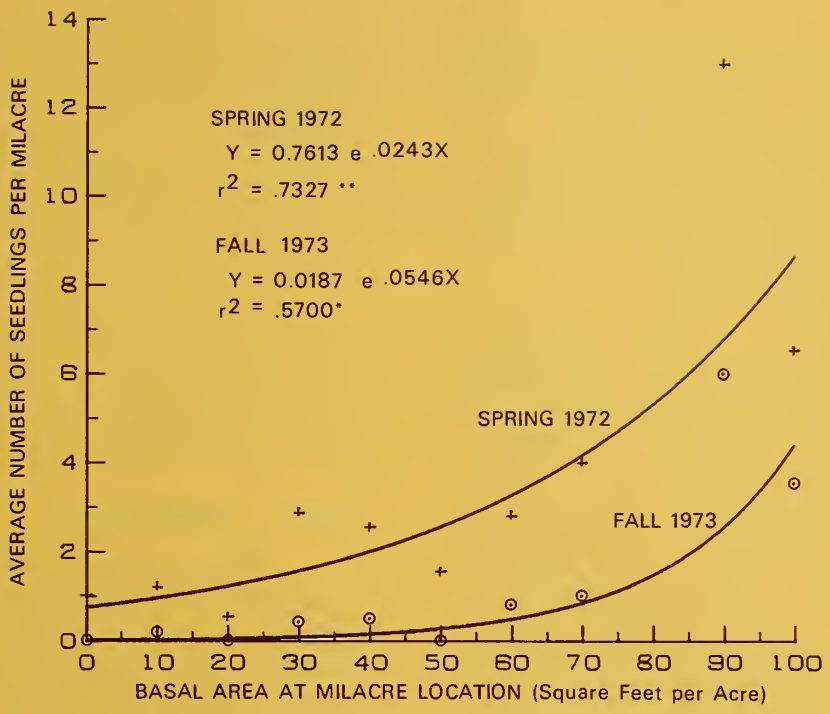

Figure 1.--Relation between density of residual stand and average number of grand fir seedlings in spring 1972 and fall 1973.

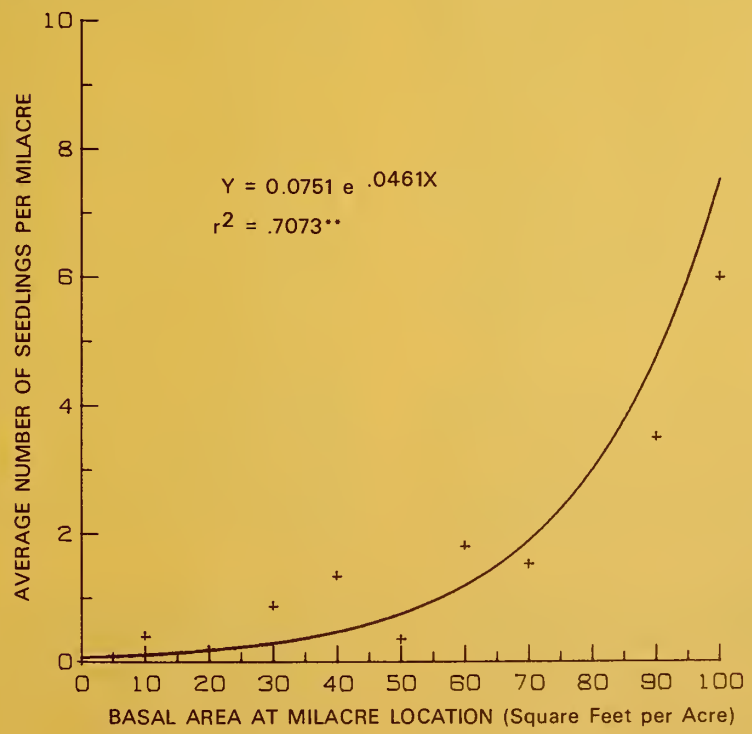

Figure 2.--Relation between density of residual stand and average number of mountain hemlock seedlings, spring 1972.

complete mortality of hemlock seedlings occurred at all stand densities above 50 ft^2 per acre (11.5 m^2 per hectare). Hemlock mortality probably would have reached 100 percent on all milacres except for some survival that can be attributed to microclimate modification by slash or a more favorable aspect.

When using the shelterwood method in the general forest zone, residual stand density should be reduced to the minimum level at which an acceptable amount of regeneration will be obtained, so that the established reproduction will not be damaged or destroyed by the removal of excess trees. Depending on the definition of acceptable stocking of reproduction, the amount of overstory needed to obtain such stocking can be estimated from the results of this study. For example, if 1,200 grand fir seedlings per acre (2,964 per hectare) are considered to be sufficient at the end of the second growing season, then residual stand density probably should be no less than 80 ft^2 of basal area per acre (18 m^2 per hectare)(fig. 1). In order to obtain adequate survival of mountain hemlock seedlings, overstory density probably should be considerably higher--more than 100 ft^2 per acre (23 m^2 per hectare)--but the density needed cannot be estimated from this study because survival was poor at all levels.

It should be emphasized that the results of this study are based on limited data from a single area and therefore are not intended to be the final answer to natural regeneration of fir and hemlock in relation to residual overstory.

The possible loss of the residual stand from windthrow should also be considered when using the shelterwood method in unmanaged stands such as these where the root depth is limited because of shallow soils. A relatively light cut is indicated because trees growing in dense stands have not developed the windfirmness needed to resist greater wind stresses resulting from heavy partial cuts; the shallow root system further increases the risk of blowdown. The risk of blowdown can be reduced by leaving dominant, full-crowned trees which are the most windfirm and also the best seed producers (Gordon 1973). An average of 1 to 2 trees per acre (3 to 5 per hectare) have been blown down in the study area in the 2 years since cutting.

Soil and Seedling Moisture Stress

Despite the severe drought which occurred in eastern Oregon in 1973, soil water was readily available throughout the summer; and seedlings never reached critical stress levels. The soil matric potential at the 6-inch (15-cm) depth was never less than -0.2 bars during the summer and was only about -0.1 or -0.2 bars at all depths at each measurement period (table 3).

The average peak moisture stress of grand fir seedlings during July and August was never less than -15 bars (fig. 3), which is well above stress levels where seedlings begin to die from drought (stress increases as values in bars become more negative). The peak stress occurred at 1300 hours at each date. Seedlings were under less moisture stress on August 31 than earlier in the summer. This is probably due to less solar radiation at this time, since soil moisture stress was relatively constant throughout the summer.

Seedling moisture stress measurements taken from 0400 to 2000 on June 26 showed the typical pattern of increasing stress until midday, followed by a decline in the afternoon (fig. 4). Stress increased from the predawn equilibrium values of

Table 3.--*Soil moisture content by weight and tension (matric potential), by depth and date (1973)* [1/]

Depth (inches)	June 26		July 13		August 7		August 31	
	Content	Tension	Content	Tension	Content	Tension	Content	Tension
	Percent	*Bars*	*Percent*	*Bars*	*Percent*	*Bars*	*Percent*	*Bars*
6	31.6	-0.1	31.7	-0.1	22.4	-0.2	21.1	-0.2
12	41.9	-.1	29.0	-.1	30.6	-.1	27.5	-.1
18	39.4	-.1	30.8	-.1	28.7	-.1	26.3	-.2
24	40.8	-.1	35.2	-.1	27.4	-.3	25.2	-.4

[1/] Each value is the mean of three replications.

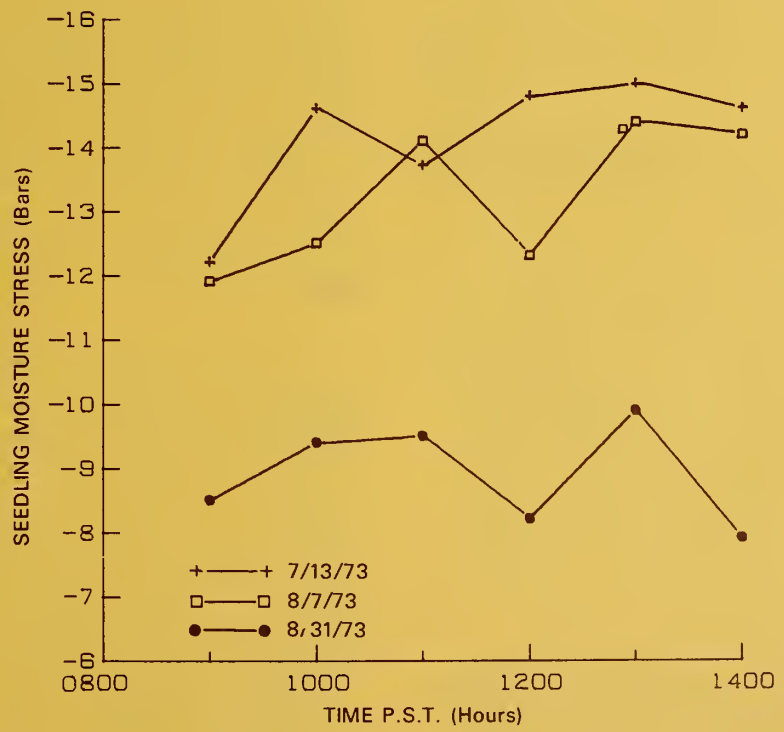

Figure 3.--Peak plant moisture stresses in grand fir seedlings on three dates, summer 1973. Each point is the mean of four seedlings.

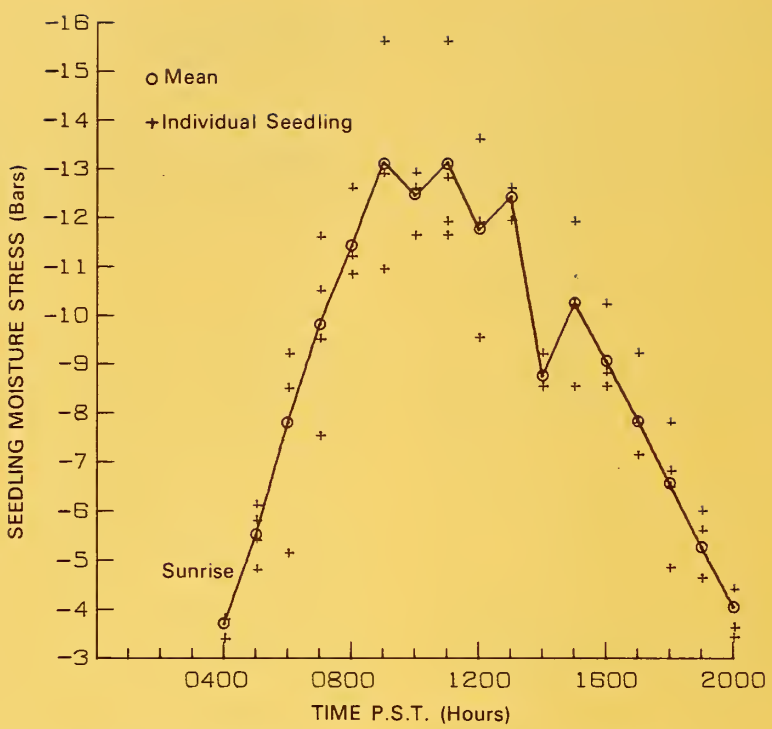

Figure 4.--Plant moisture stresses in grand fir seedlings, June 26, 1973.

-3.5 bars to -13 bars at 0900 and 1100 hours and decreased linearly after 1500 hours. Seedling recovery from peak stress values was very rapid, almost reaching the predawn value by 2000 hours. Sampling variability generally was the smallest when seedlings were not stressed. The standard error of the mean ranged from ± 0.1 bar at 0400 hours to ± 1.0 bar at 0900 hours for a mean derived from four seedlings.

The results of the soil and seedling moisture stress measurements strongly suggest that drought is not a mortality factor for grand fir seedlings after the first growing season when competing understory vegetation is absent. Similar conclusions were reached by Jones (1972) after measuring moisture stresses of mixed conifers in Arizona.

Surface Temperatures

Surface temperatures in the study area during the summer reached levels generally considered lethal to seedlings. There was little difference between the percentage of Tempils that melted in open areas and those receiving partial shade (table 4). Apparently enough direct sunlight was received in the partially shaded areas to result in surface temperatures equivalent to those found in the open areas. The temperature on the mineral soil surface was not as high as on litter in both open and partially shaded areas. None of the 163° F (72.8° C) Tempils melted on mineral soil, but 10 percent melted on litter surface, and 80 percent of the 150° F (65.6° C) Tempils melted on litter compared with only 10 percent on mineral soil.

Table 4.--*Surface temperatures, by seedbed condition and shade*

Seedbed condition	Tempil melting point (°F)			
	125	138	150	163
	- - - Percent of pellets melted - - -			
		Open		
Mineral soil	100	60	10	0
Litter	100	100	80	10
		Partial shade		
Mineral soil	100	40	10	0
Litter	100	100	80	10

Although surface temperatures were in the lethal range for young seedlings, no data are available regarding the length of exposure to these temperatures or the response of fir or hemlock seedlings to various high temperature-time combinations. Because it is not the temperature alone but also the duration of seedling exposure that determines mortality, no conclusions as to the importance of these temperatures in causing seedling mortality can be made at this time.

CONCLUSIONS

Although based on only a single case history, the information presented here should prove useful as a first approximation in determining density of residual overstory to leave when using the shelterwood method in upper-slope fir-hemlock stands in the central Oregon Cascades at least for regeneration of grand fir. It is apparent that seedlings of shade-tolerant species such as grand fir and mountain hemlock require a considerable amount of overstory protection in order to live through the first 2 years after germination. To obtain satisfactory numbers of grand fir seedlings, residual stand density probably should be no less than about 80 ft^2 per acre (18 m^2 per hectare).

It appears that mountain hemlock seedlings are much more sensitive to microclimatic extremes than grand fir seedlings, since hemlock survival was poor even at the highest overstory densities. These results, together with the probable windthrow loss of hemlock after heavy cutting, indicate that overstory density should be high (more than 100 ft^2 per acre; 23 m^2 per hectare) if hemlock makes up a large percentage of the stand and significant amounts of hemlock reproduction are desired. Selection of the tallest, large-crowned trees to make up the residual stand should help to minimize loss from windthrow. More experience and research is needed with shelterwood cuttings at high densities in mountain hemlock stands to determine suitable residual stocking levels.

Land managers are cautioned not to use the relationship between residual overstory and seedlings per acre as a precise predictor of regeneration success. These are only rough estimates, because seedling establishment and survival may vary greatly depending upon such factors as seed supply, weather and seedbed conditions, and animal populations.

Drought is a probable cause of seedling mortality during the first growing season if root growth does not keep pace with the drying front in the soil. After the first summer, however, there seems to be little chance of drought-caused mortality.

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